

Analysis of Evacuation Traces

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ABSTRACT

Given the spatio-temporal data of the people in a building where an explosive is detonated, we use visual analytics techniques to analyse the events in the building before, during and after the explosion. The data contains the coordinates of all the people in the building, at each time-step considered around the explosion. We developed a visualization tool for finding out the perpetrators as well as casualties and we present our analysis here.

Index Terms: I.5.2 [Computing Methodologies]: Pattern Recognition—Design Methodology ; I.5.5 [Computing Methodologies]: Pattern Recognition—Implementation ;

1 INTRODUCTION

The premise of the spatio-temporal data is that in August 2007, a small improvised explosive device was set off at a Miami, Florida Department of Health (DOH) building. The explosion resulted in casualties and moderate damage. Around then, this DOH branch had conflicted with the local Paraiso religious groups as DOH provided medical care to Paraiso children in public schools and other public facilities. The Paraiso religion with its growing popularity in Florida and other southern states, strongly opposes to state-administered health care and encourages health care at home provided by the family. This led to suspicions on the Paraiso supporters which they obviously deny.

To confirm the perpetrators, witnesses and casualties, we use the data obtained from the RFID sensors that each person in the building had on them during the event. The data consists of 82 RFID-identification numbers and 837 time-steps during which the event occurs. The pre- and post- behavioral patterns of the people in the building will give us a lot of insight on when and where the device was detonated, and who is likely the person who caused it. It also confirms the evacuation patterns most people follow in finding the nearest exit.

2 VISUALIZATION TOOL

We developed and used a visualization tool to analyse the spatio-temporal data of the people in the building. Our tool allows us to step forward and backwards in time to study the paths each of the person take until the specific time-step, as shown in Figure 2. The trace of each person is rendered as a line which gets updated with time. The visualization tool has been developed using OpenGL and C++.

3 VISUAL ANALYSIS

3.1 Overview

On a first look of the complete animation gives us an idea of the exits used for evacuation.

There are possibly three exits in the south, presumably is the front of the building. The three exits, as shown in Figure 2, are in the leftmost, left center, and rightmost. There is a safe spot in the

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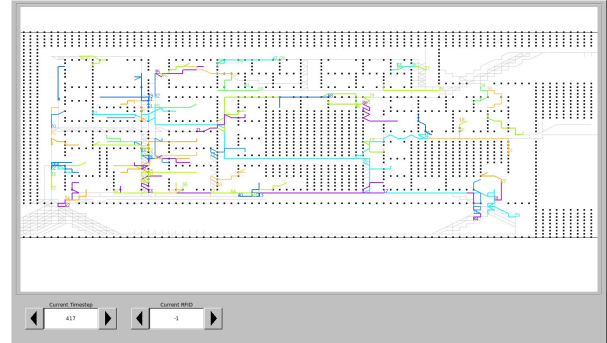


Figure 1: Screenshot of the Visualization Tool at timestep 417: the black dots indicate solid structure, and each RFID has a unique color and its corresponding line shows the trace until timestep 417.

Location	#people at the location	RFIDs
Front: leftmost	24	4 6 7 10 11 14 22 23 33 35 41 43 46 48 52 54 57 61 62 67 68 70 75 77
Front: left center	27	0 2 5 8 9 12 13 15 16 25 26 31 34 40 42 44 45 49 55 63 64 66 71 72 74 79 81
Front: rightmost	5	17 27 29 38 53
Back: right enclosure	11	3 20 24 28 30 32 37 51 58 73 80
Interior of the building	15	1 18 19 21 36 39 47 50 56 59 60 65 69 76 78

Table 1: Last locations of all RFIDs

back of the building; where a few people are crowded, which is in the rightmost enclosure in the back. Most likely, this is a conference room with a lot of furniture in between which explains the zigzag path taken by the entrants into the room. This room can be considered safe owing to its thick walls. The final positions of RFIDs can be grouped as shown in Table 1.

3.2 Explosive detonation

We studied the different paths taken by various individuals over the entire period of time, and concluded that the cell (66x32) is where the explosive was set off at around time-step 370-74, and was planted by RFID 21. Our reasons that led to the conclusion:

- Around timestep 374, a lot of people on the left side of the building start to move which continues to being evacuation traces.
- There are upto 6 casualties in the right side of the building

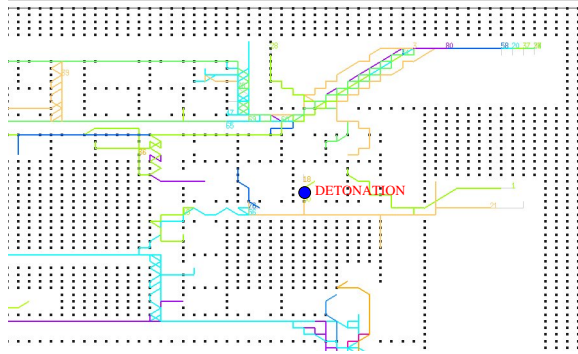


Figure 2: Closeup shot of the Visualization Tool at timestep 600 showing the region of impact from detonation.

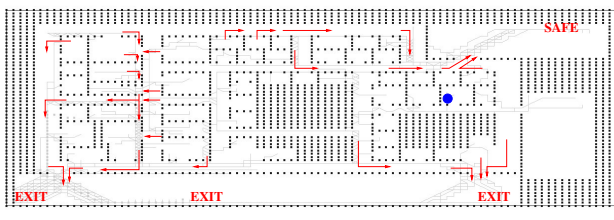


Figure 3: Building map: The black dots indicate solid structure, the grey lines indicate the possible paths all the 82 persons took in 837 time-steps, the red arrows indicate the general evacuation patterns most people followed and the blue dot indicates possible spot of detonation, 'Exit' implies exit from the building, 'Safe' is a spot a few people went to during evacuation.

soon after this timestep. RFIDs 18, 50, 76, 56, 19 and 1, who are close to each other, stop movements are at timesteps 383, 384, 403, 413, 439 and 463, respectively. Since RFIDs 18 and 50 are the first ones to be casualties and they happen to be in the same room, the likelihood of the device being in that room is very high.

- The only other person who enters the room of RFIDs 18 and 50 is RFID 21. 21 moves out of the room and waits around the corner of the room at the detonation time which possibly can be explained by the hypothesis that he was remotely detonating the device at the time.

3.3 Strange behavioral patterns

Certain people in the building show strange behavioral patterns. These scenarios and our hypothesis for the same are explained here:

- RFID 28 moves a lot in the beginning as well, and eventually moves towards the safe spot, stays away from the crowd in the other end of the enclosure and at time=591 he stops moving. It is highly improbable he is injured. He is more likely a witness than a suspect because if he were a suspect, he will move with the crowd to avoid detection and if he were not a witness, he would still have moved with the crowd as a natural behavior.
- RFID 21 is clearly the one who planted the device from our hypothesis. However soon after the detonation the dynamics between RFIDs 28 and 1, who was in the adjacent room of the detonation, is strange. RFID 28 moves away from the detonation, but moves into another enclosure after following 1. 1 stops moving at timestep 479, indicating that he has been impacted by the explosion by virtue of vicinity. However, 21 and 1 never come in touch in the enclosure, 21 entering much after 1 stops moving. 21 eventually stops moving at timestep

520. Our hypothesis for this is that 1 and 21 are accomplices and they are both injured and are hence casualties themselves.

- RFID 56 is a possible suspect. He moves around a lot in the beginning and after the bomb detonates, he walks in the direction of the device rather than away from it. He tries to come in contact with RFID 76 who is in the adjacent room where the device is set off. Soon after their contact, 76 stops moving, and 56 stops moving after a little while. We hypothesize that 76 is likely a witness since 21 visits his room before planting the device in the neighboring room. 56 attacks 76 to protect 21. However due to proximity of 76 to the explosion, 76 is likely very injured already. 56 becomes a casualty either by inhaling poisonous fumes from the explosion or in a rare event, 76 attacks him back.
- RFID 19 accidentally moves towards the scene of explosion and becomes the casualty, very probably due to the poisonous fumes from the explosion.
- RFID 36 moves only once during the entire time-period. His movement occurs much before the device detonates at timestep 243, which implies that he is very unlikely a casualty. It brings us to believe that he is a suspect and has thrown away his RFID badge to avoid detection.
- RFIDs 59, 64, 40, 77 are possible witnesses, whereas RFID 13 is a possible suspect, who meets with RFID 44 at timestep 198. 59 is later followed by 13 during which 59 stops movement at timestep 689, possibly is attacked by 13, while the others escape.
- RFID 39 meets with RFID 78 at timestep 513 and then retraces his path and moves around in a closed corridor until timestep 573. 78 moves last at timestep 619 and 39 moves last at timestep 653. Their movements prior to their meeting indicate evacuation. However the pattern changes after they meet. Possibly there has been an attack between the two at the meeting point, and both get seriously injured. Their injuries are not induced by the device because they are at a safe distance from the device at the time of trigger. It is very likely that 39 is a suspect, as he moves in the direction opposite to the rest of the occupants of the room he is in. That leads us to believe that somehow 78 is a witness.

4 CONCLUSION

From the animation of the events using our visualization tool, as shown in Figures 2 and 2, we have been able to conclude that RFIDs trapped in the interior of the building except for RFID 36 are all casualties. RFIDs 28, 40, 59, 64, 76, 77 and 78 are possible witnesses. RFIDs 1, 13, 21, 36, 39, and 56 are possibly the perpetrators. From our visual analysis we have concluded that the device was planted by RFID 21 at (66, 32) cell and was detonated around timestep 370-374.

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